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AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

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AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

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14. ABSTRACT

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2 items enclosed = 210 + 213

④ Paper Rec'd After 30-day Deadline = { 22 days until Deadline }

FILE

MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO)

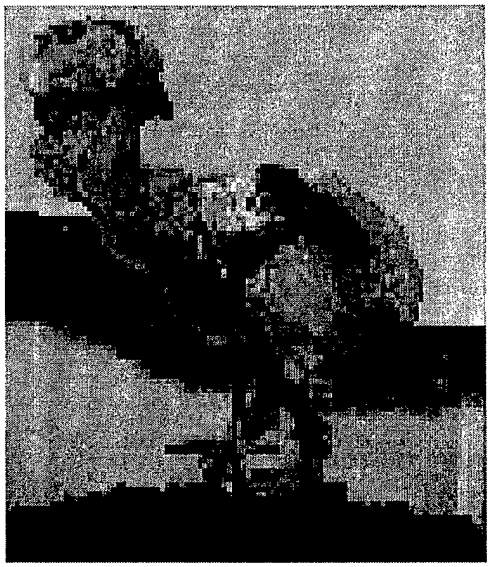
03 Sept 2002

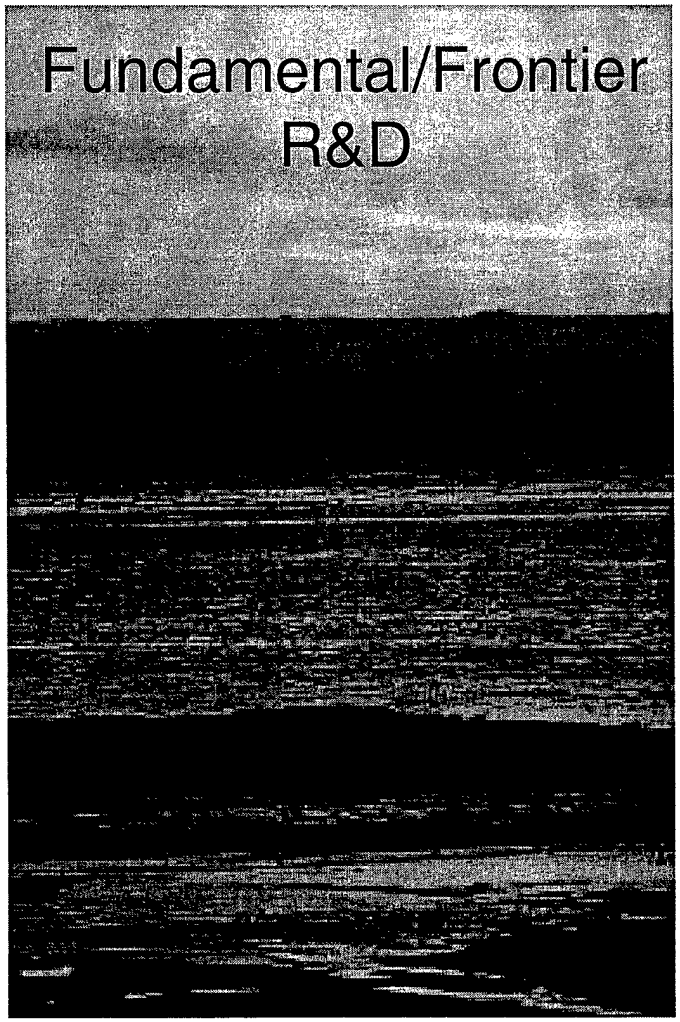
SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2002-213**
Shawn Phillips (PRSM), "AFRL POSS Applications Research" (viewgraphs)

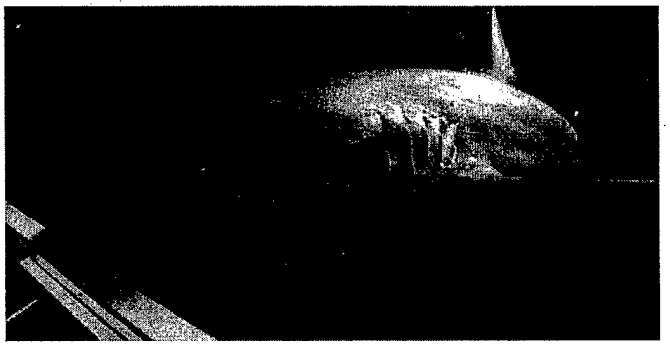
POSS Nanotechnology Conference **(Statement A)**
(Huntington Beach, CA, 25-27 September 2002) **(Deadline: 25 Sept 02)**

AFRL POSS®
Applications Research

Dr. Shawn Phillips



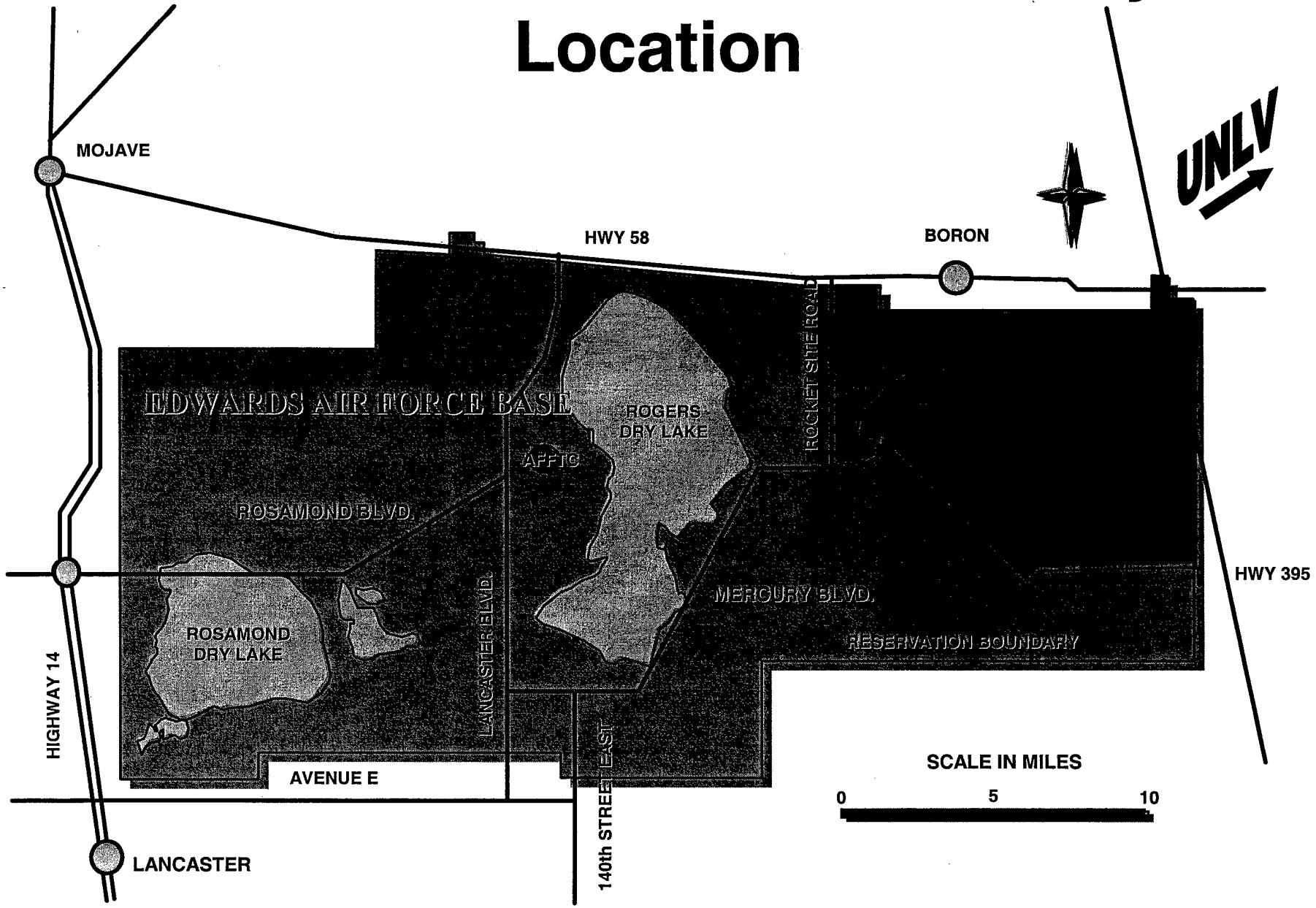




Applications
R&D

Technology
Transfer/Transition

Air Force Research Laboratory Location

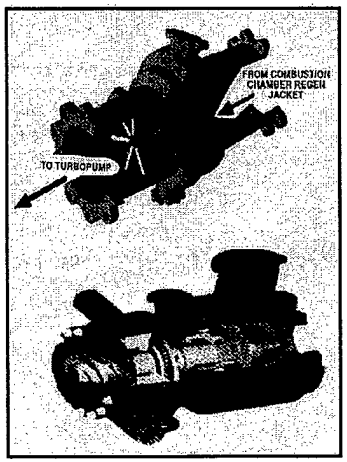


Air Force Research Laboratory
Edwards AFB / Propulsion Directorate

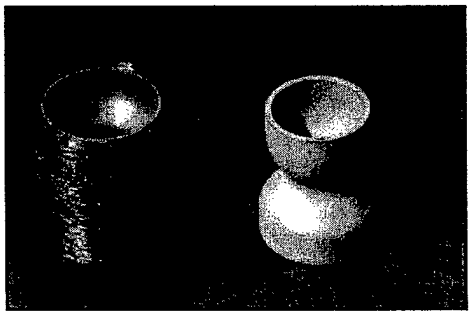
MISSION STATEMENT

Create and Transition Propulsion and Power Technology for Military Dominance of Air and Space

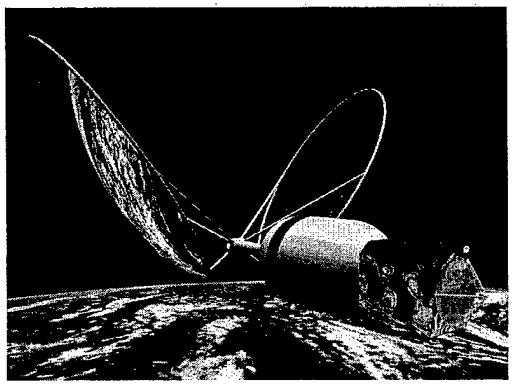
(IHPRPT 2x)



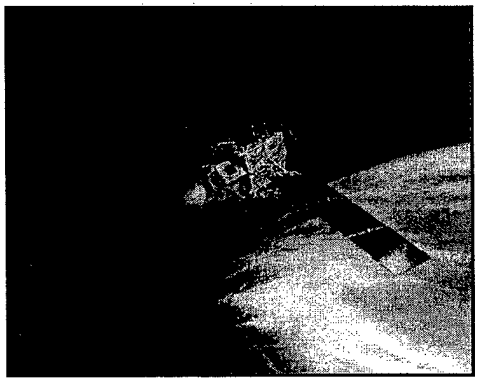
IPD



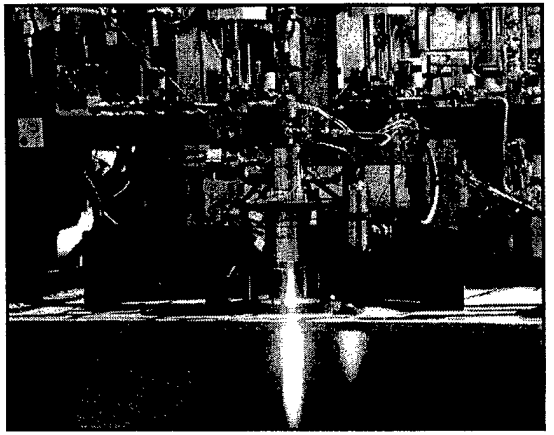
CARBON / CARBON



OTV



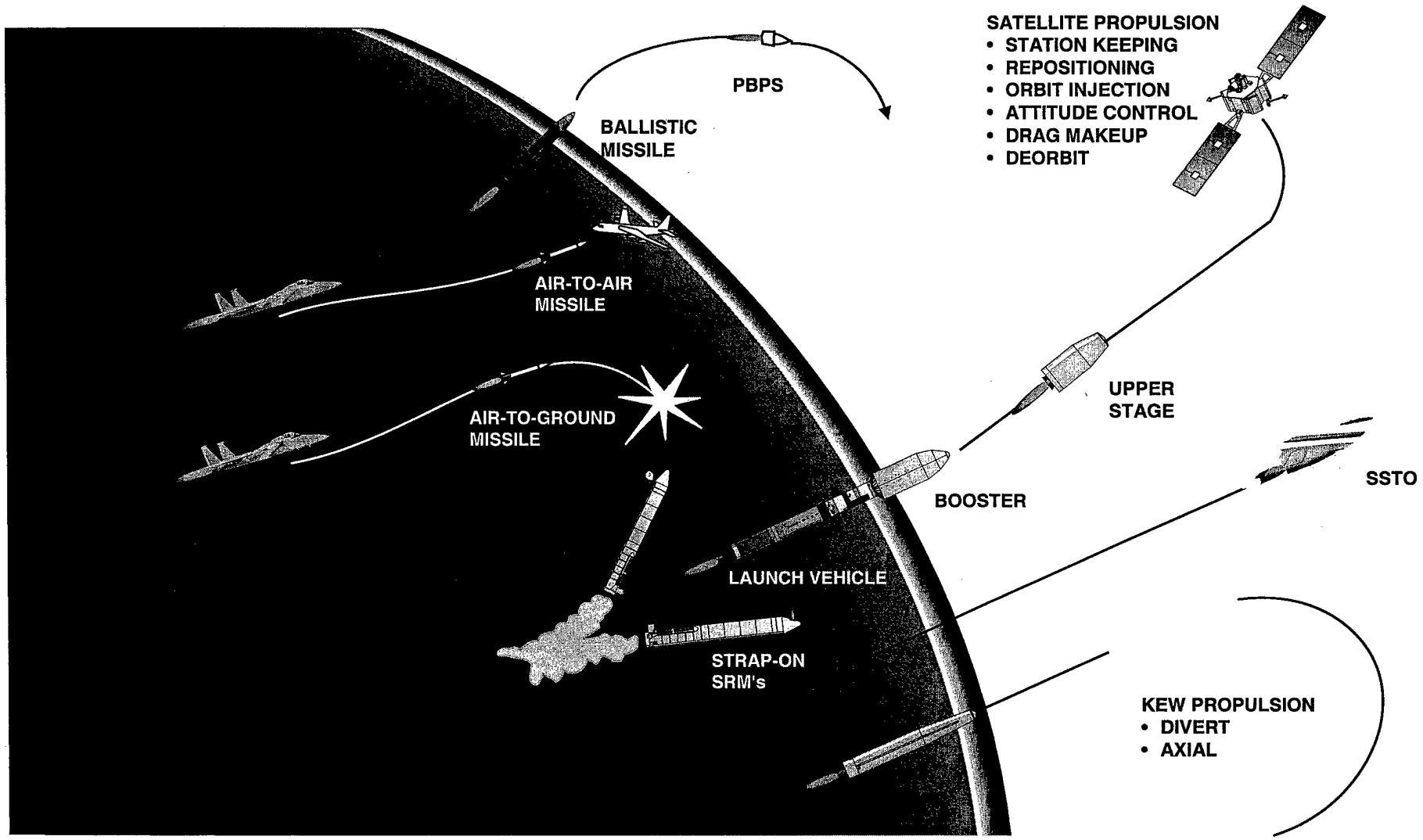
ESEX



HEDM

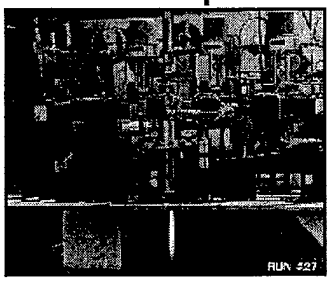
Rocket Propulsion Technology

Fundamental to all Space & Missile Systems

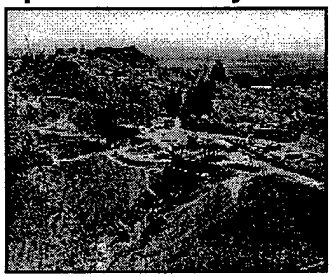


Edwards Research Site
Propulsion Directorate

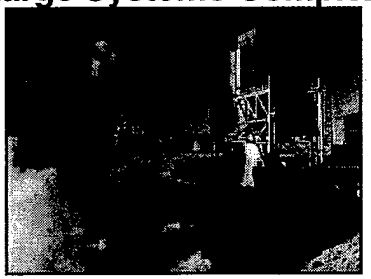
Satellite Propulsion



Experimental Systems



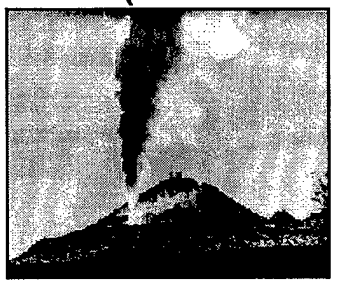
Large Systems Complex



TO 10,000,000 LB THRUST
FIXED OR SPUN
HORIZONTAL OR VERTICAL ORIENTATION
ENVIRONMENTAL CONDITIONING
HIGH HAZARD

Small Solid Components

High Thrust (Solid and Liquid)



VEHICLE FLIGHT/HOVER TESTING

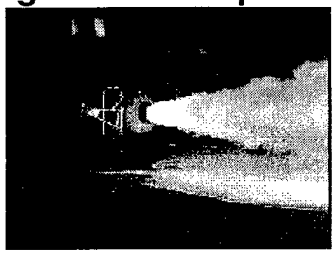
REDUCED SMOKE PROPULSION STUDIES

SOLAR THRUSTER EXPERIMENTS

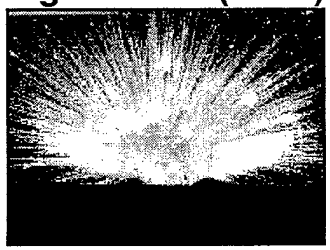
SATELLITE g LOAD STUDIES

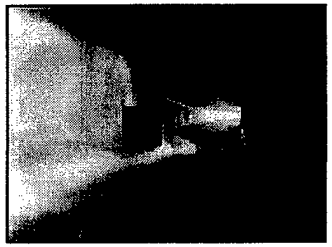
TETHERED LAUNCH CAPABILITY

Large Solid Components



High Hazard (Solid)

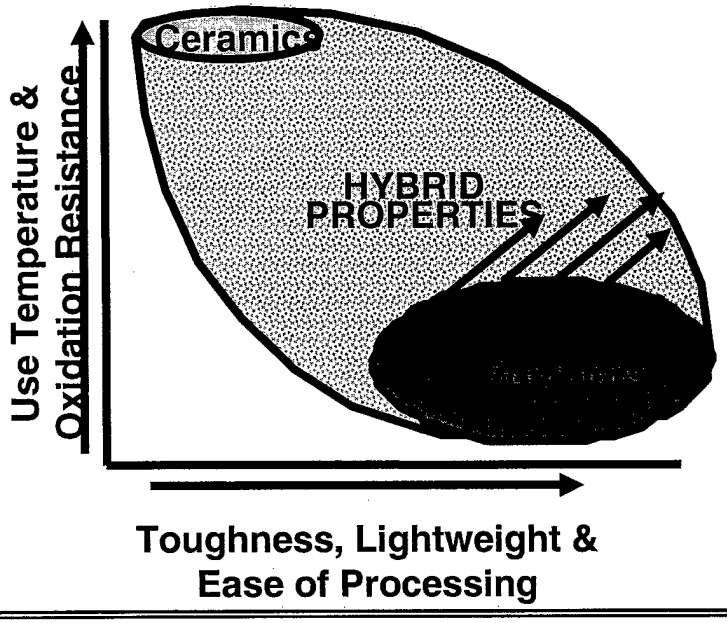




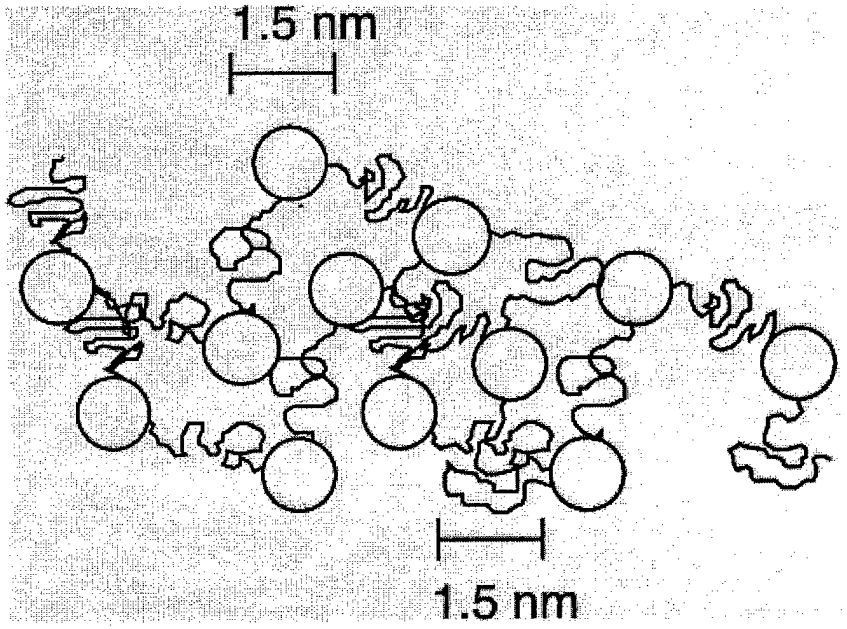
Large Liquid Components

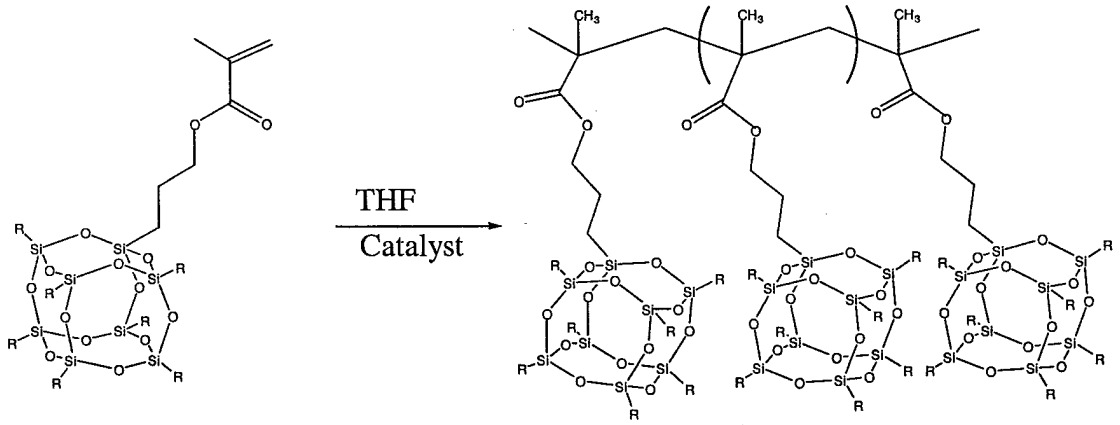
Key Aspects of POSS™ Technology

Hybrid (inorganic/organic) Composition



Nanostructured™ Chemical Reinforcement



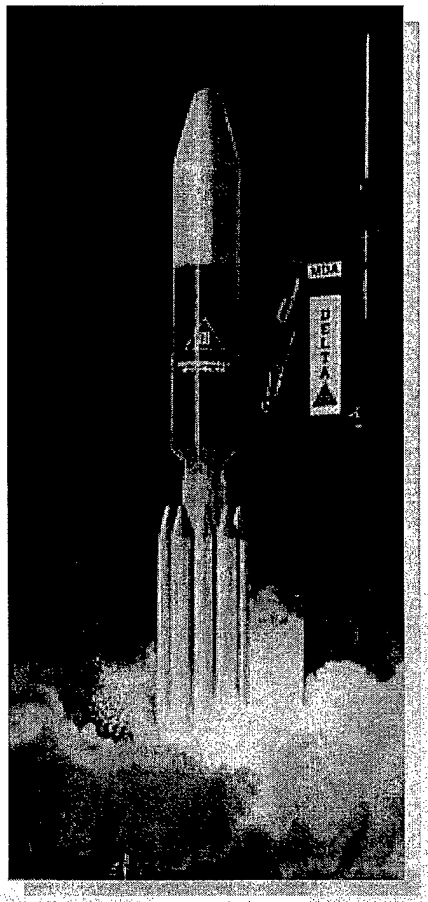


POSS™ technology does not require manufacturers to retool or alter existing processes.

Lichtenhan et. al. *Macromolecules* **1993**, *26*, 2141.
Lichtenhan, *Polym. Mater. Encyclopedia* **1996**, *10*, 7768.

POSS® for Propulsion & Beyond

High-Performance Nanostructured Polymers

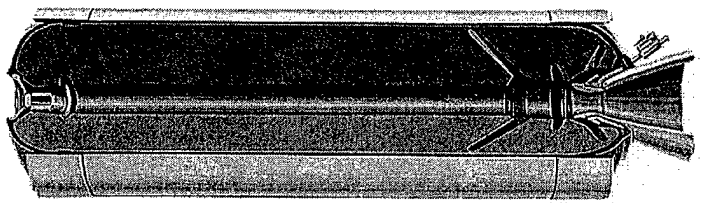


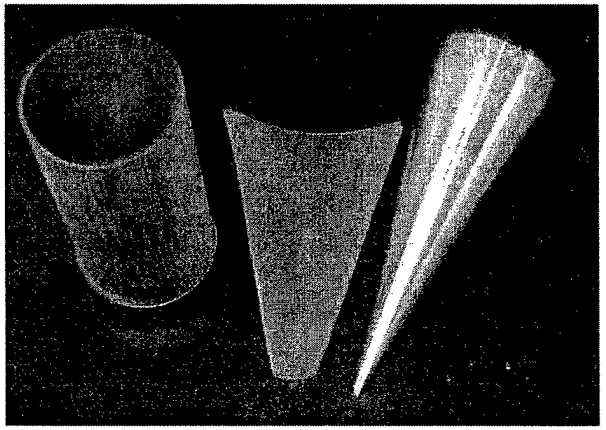
- High temperature case and motor insulation for solid rockets
- Plastic tubing and ducting for liquid rockets engines
- Space-survivable materials and coatings
- High-temperature canopies and hybrid lubricants

POSS Nanotechnology Offers Versatility!

Solid Rocket Motor Insulation Program

Case Insulation





POSS-Insulation

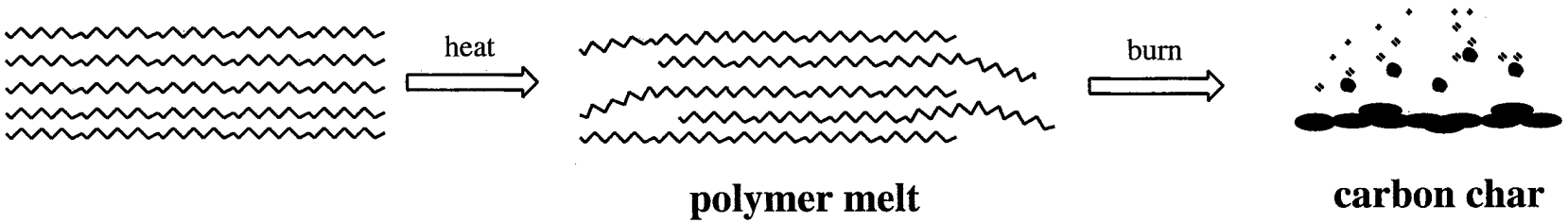
[redacted]

Why POSS?

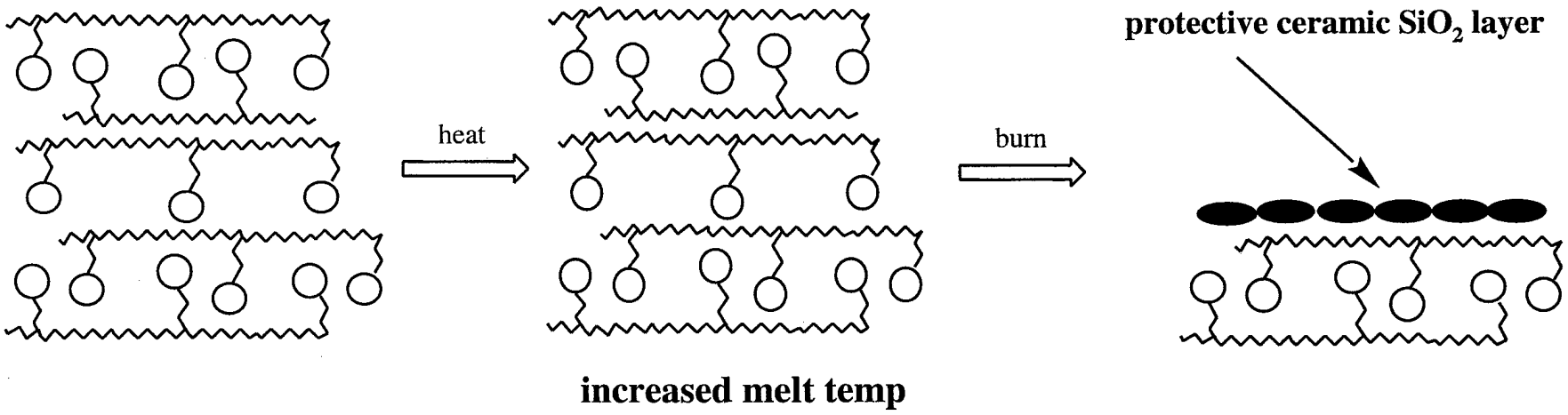
-need inorganic material with polymer flexibility
-ability to incorporate very high loadings
-processable using traditional equipment!!
-maintain mechanical property range
-physical cross-linker for TPEs

POSS for Ablative Materials

Traditional Polymer

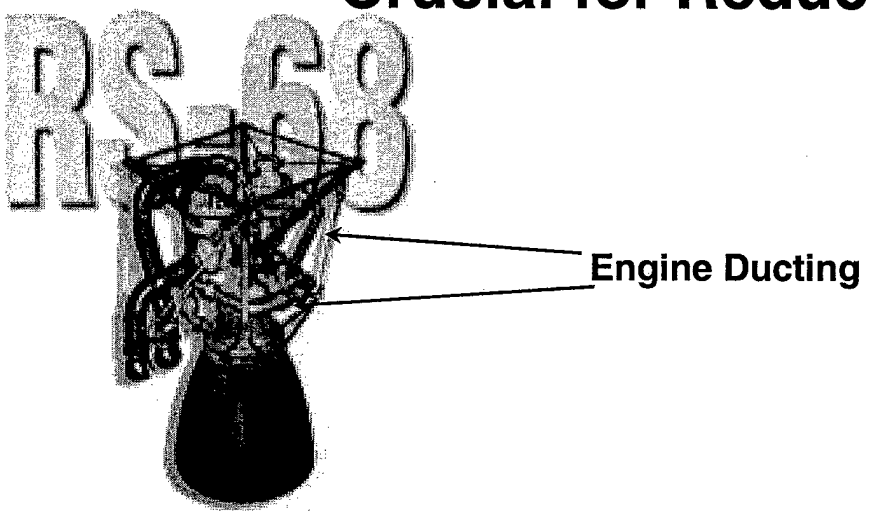


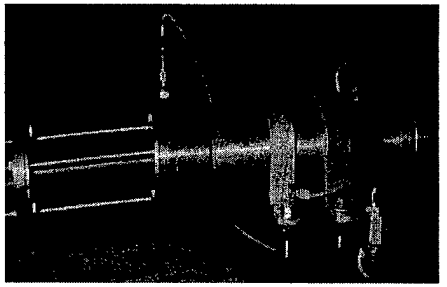
POSS Polymer



The Silicon to Oxygen ratio of 1:1.5 may be the key!!!

Liquid Rocket Engines
Crucial for Reducing Weight and Cost





Polymer Tube/Case Hot Gas Burst Tester

[redacted]

Why POSS?

-need to improve thermal & mechanical properties of SOTA polymers (PC, PPS, TPI, PEEK, PEI)

-Cornucopia of monomers for copolymerization reactions

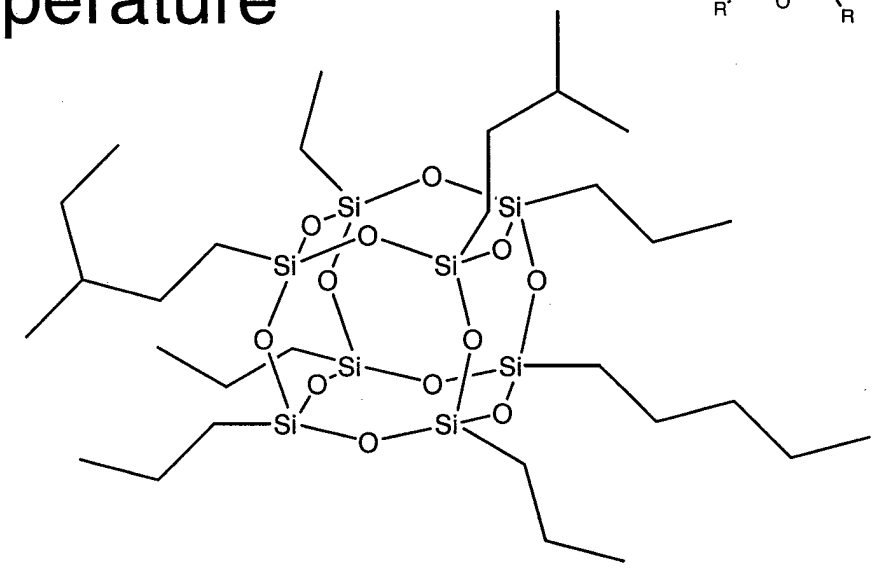
-NO CTE mismatch (cryogenic capability)

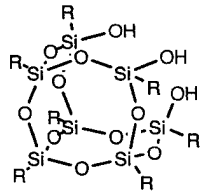
-Potential for extrusion!

POSS Materials for Aerospace

High Temperature

Hybrid Lubricant Applications

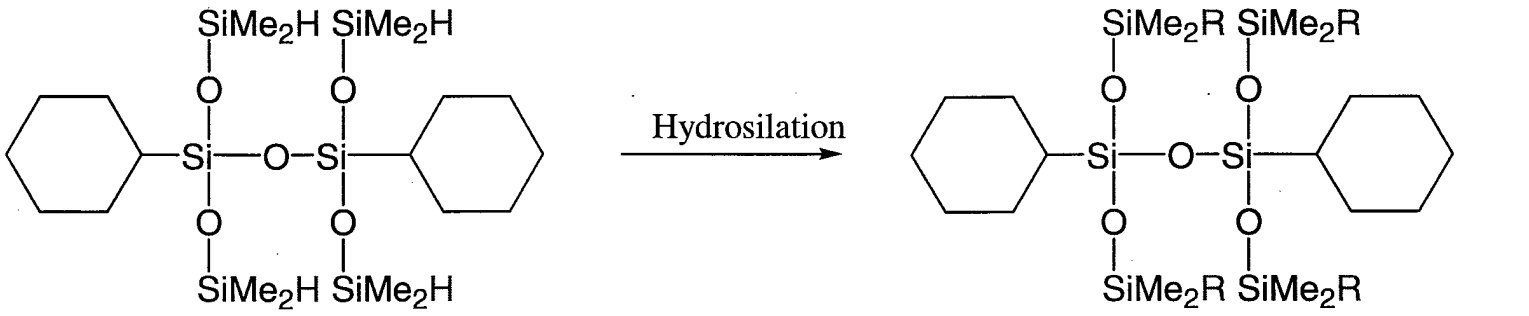




Why POSS?

- **POSS based lubricants T_{dec} = 590 °F**
- Cornucopia of monomers for compatibility and viscosity control

Generation III Lubes
CyT_2 Class

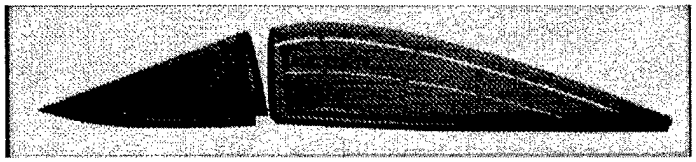


R= Decyl, Dodecyl,
Tetradecyl , all liquids at RT

When R=Decyl the viscosity at –40 °F is 4000 cP
When R=Dodecyl, the freezing point is 10 °F
Chemical and Physical Blending Studies Show that POSS follows the Rule of Mixtures
Joint Patent with Hybrid Plastics filed this year

Dual Use S&T: WMR

Jet Canopies



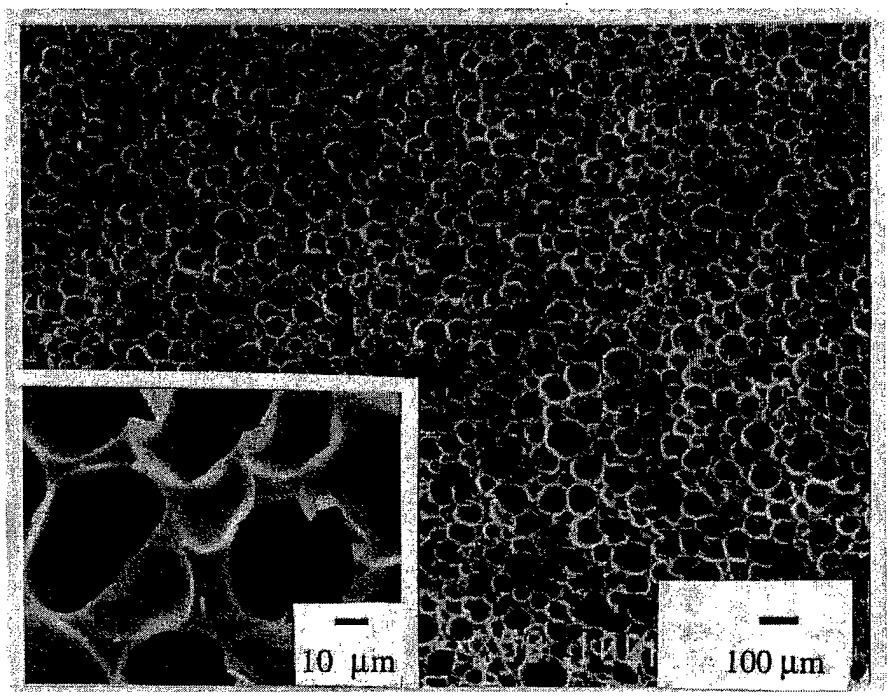
POSS-based Transparent Materials

- Mach 2x speeds limited for plastic canopy (need increased HDT)
- Target Engagement Times can be reduced by increasing flight speed

Why POSS?

POSS-PMMA increases use temp. up to 150 ºC
POSS can be optically transparent!!
POSS-PMMA readily processed via foaming
Ability to make POSS-polycarbonates also

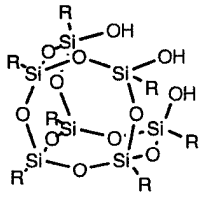
WMR's Current High Performance Foam

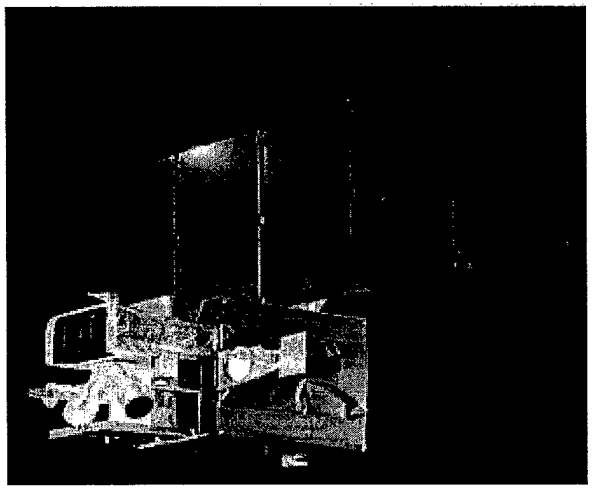


Cell Sizes can be Tailored From Nano To Several mm

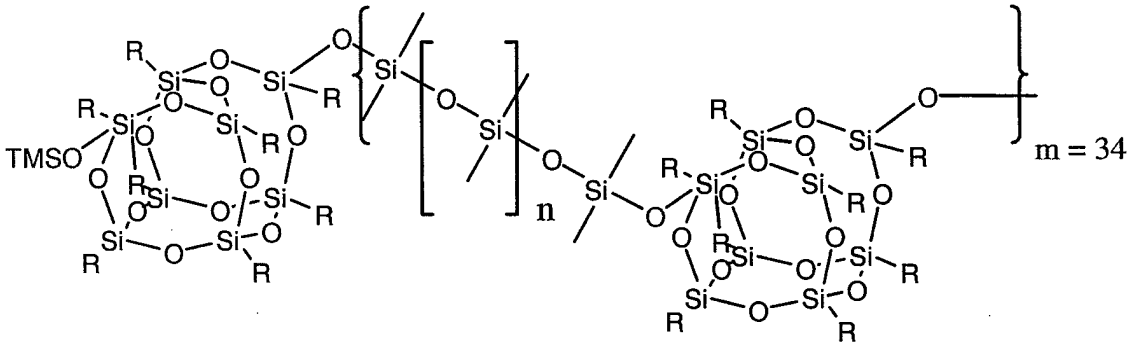
POSS Materials for Space

Critical for Increasing Lifetime





Satellites & Space Systems



POSS-PDMS copolymers

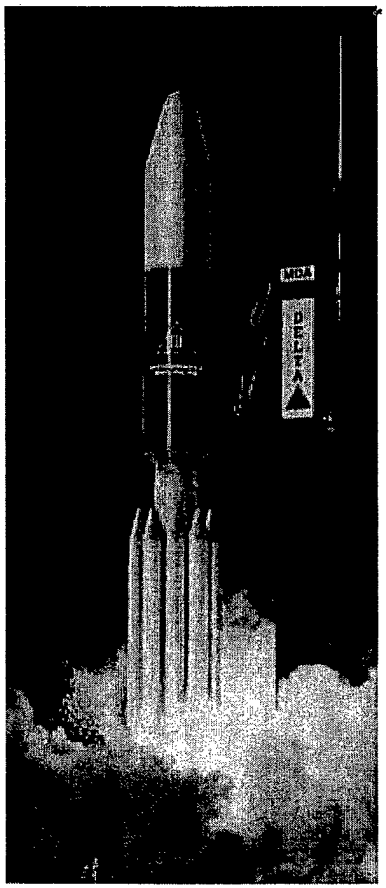
POSS Nanocomposite Payoffs

- Maximum Space Survivability
  - LEO, AO, VUV, Impact
- Lower Density 'Filler'
- High Modulus
- Resins for all Structural Applications

Simulated 3 mo. AO/VUV Exposure

- 9-20x greater AO resistance than current state of art
- Even better AO/VUV resistance
- Current NASA, Aerospace Corp., and University collaborations

Where Are We Now?



Research:

New Monomers & Feedstocks (>180) - simplicity

Control & Prediction of Property Enhancements

Production:

Multi-Ton Production Capability!!!

10-100x Reduction in Cost (monomer dependent)!!!

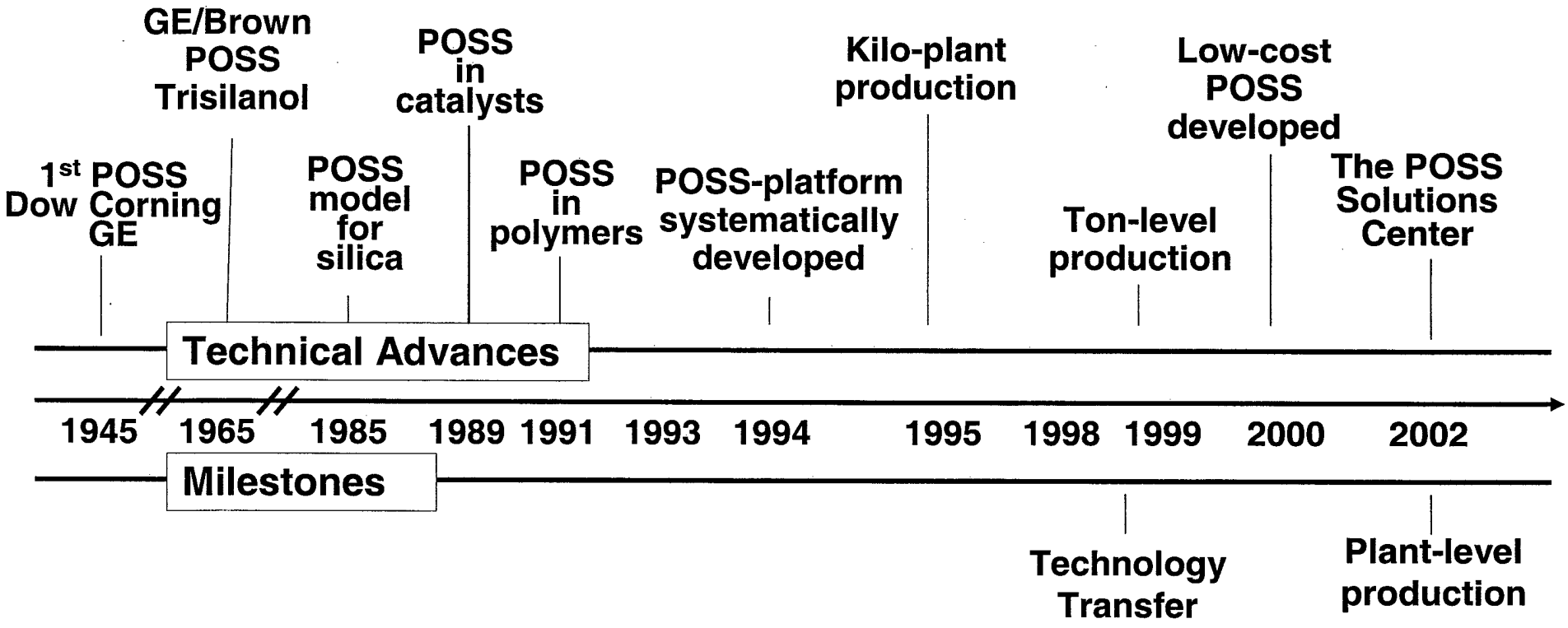
Application:

Critical & High-Risk Paths for Air Force Applications

(Insulation, Ducting, Lubricants, Space Materials)

Incorporation and R&D Testing by Numerous Companies

POSS™-Technology Timeline



UCI Air Force Hybrid Plastics

Chemistry Polymers Commercial Solutions

GE/Brown POSS Trisilanol

POSS in catalysts

Kilo-plant production

Low-cost POSS developed

1st POSS DC/GE

POSS model for silica

POSS in polymers

POSS-platform systematically developed

Ton-level production

The POSS Solutions Center

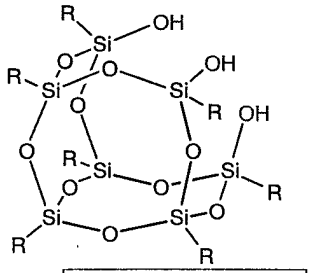
Technical Advances

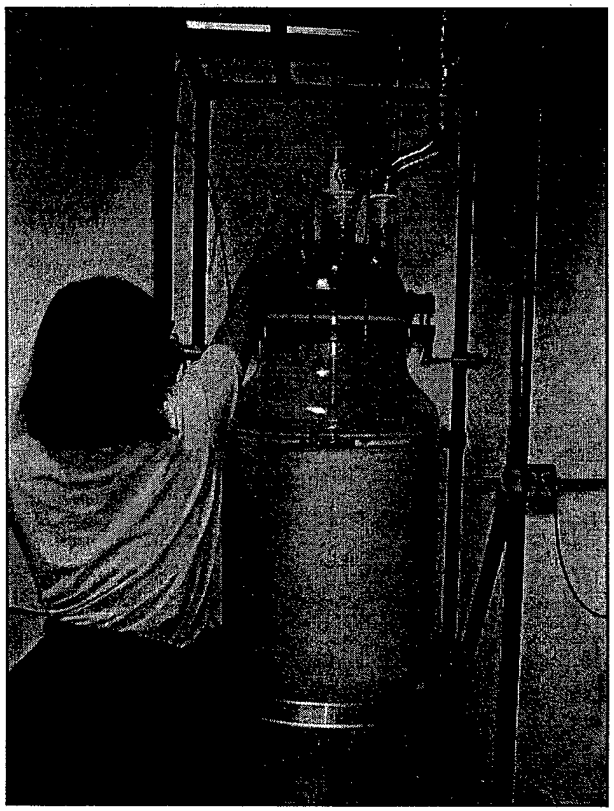
1945 1965 1985 1989 1991 1993 1994 1995 1998 1999 2000 2002

Milestones

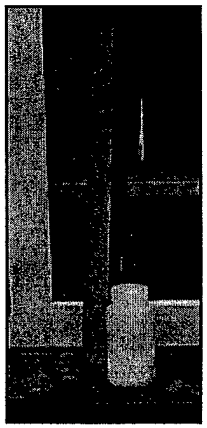
Technology Transfer

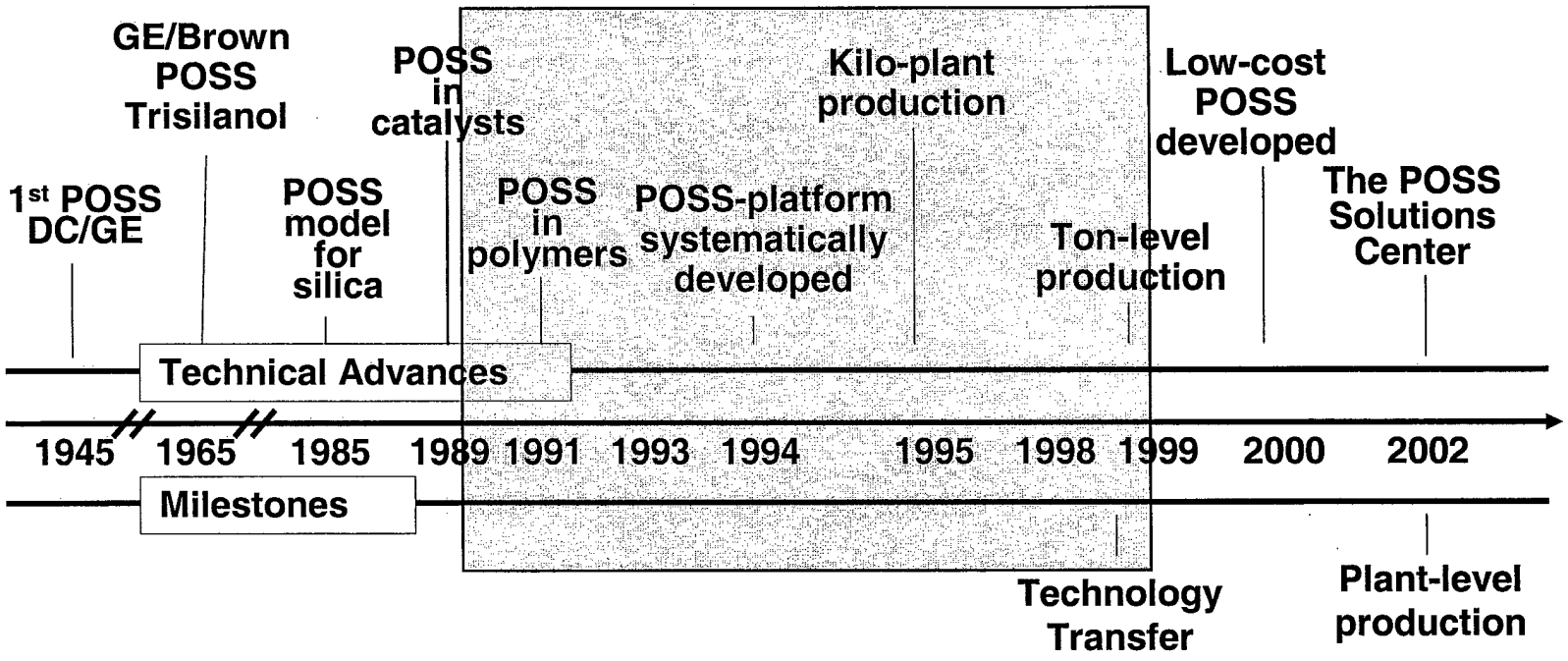
Plant-level production

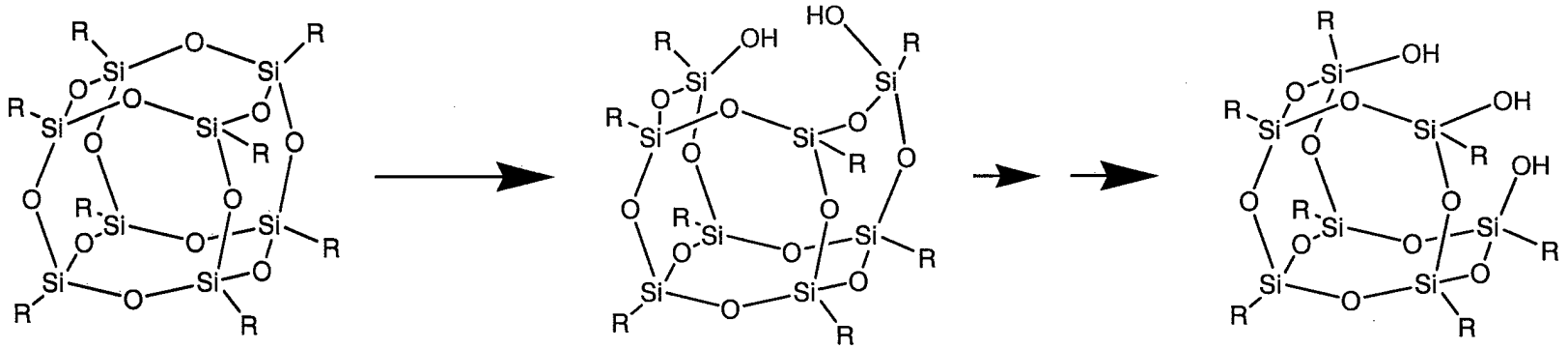




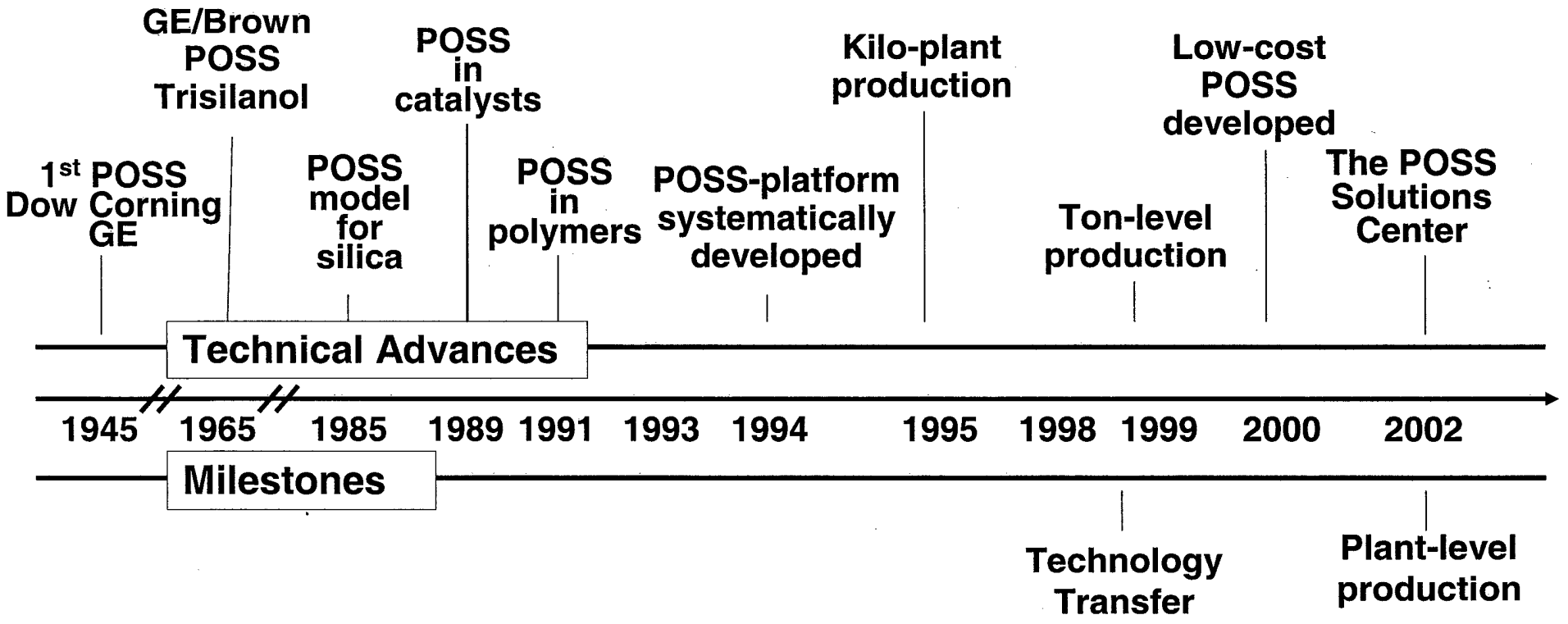
Reverse Scale-up?




GE/Brown POSS Trisilanol
POSS in catalysts
Kilo-plant production
Low-cost POSS developed
1st POSS DC/GE
POSS model for silica
POSS in polymers
POSS-platform systematically developed
Ton-level production
The POSS Solutions Center
Technical Advances
1945
1965
1985
1989
1991
1993
1994
1995
1998
1999
2000
2002
Milestones
Technology Transfer
Plant-level production



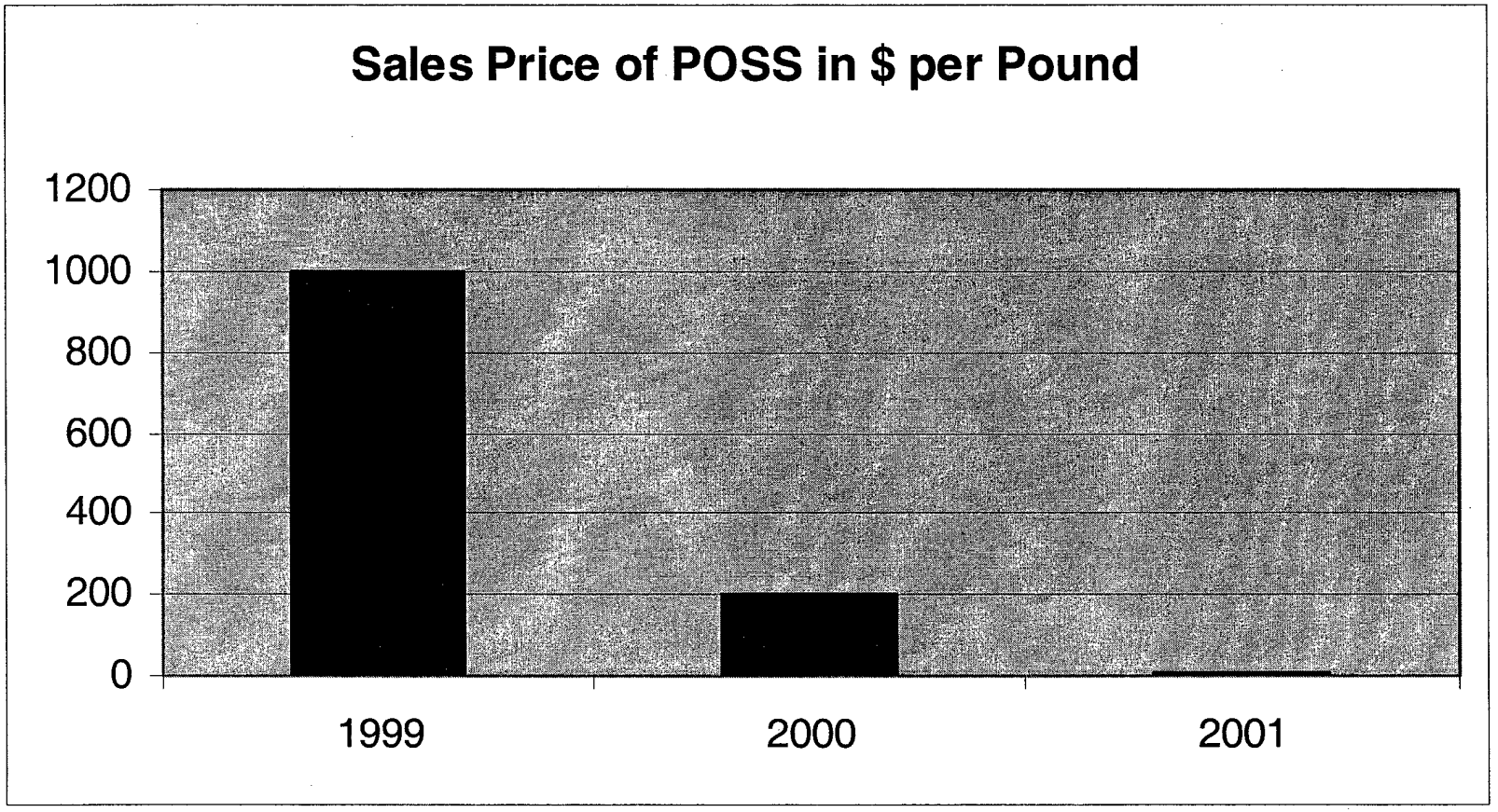
POSS™-Technology Timeline



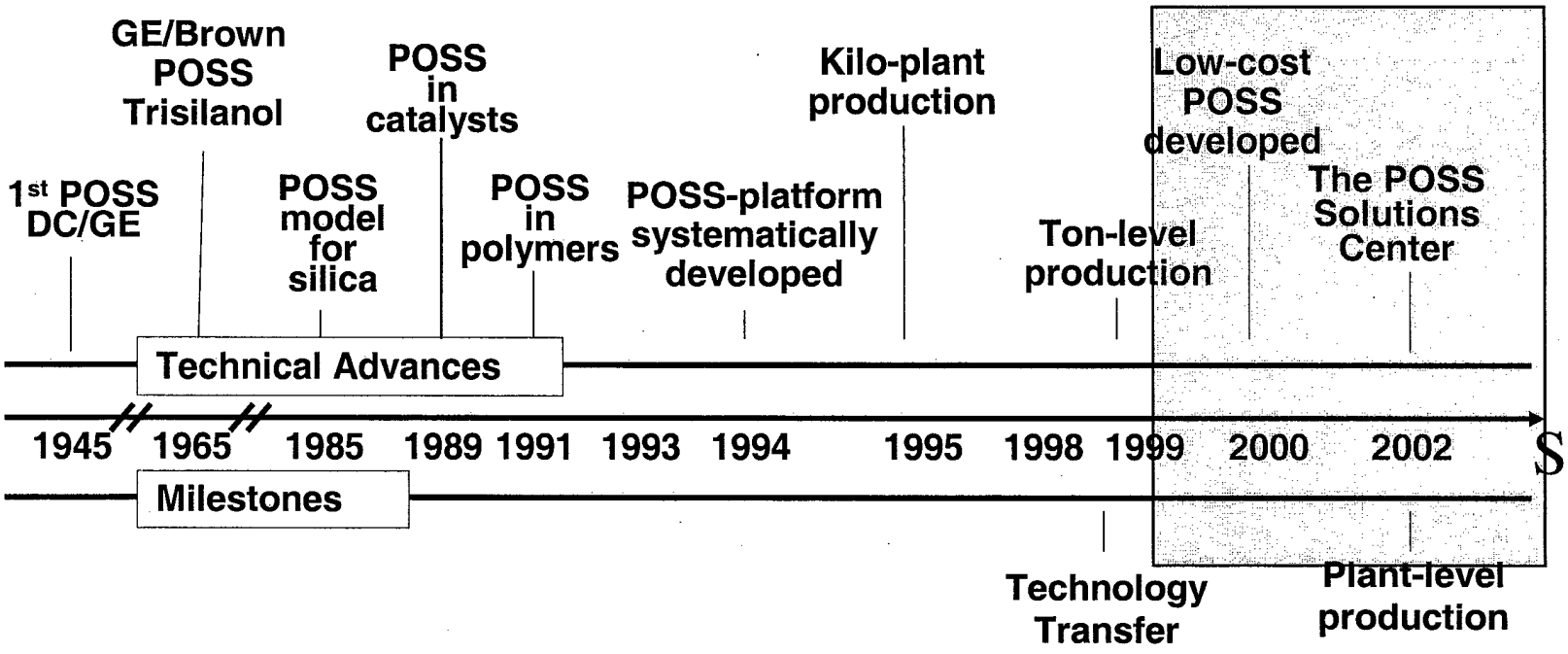
UCI Air Force Hybrid Plastics

Chemistry Polymers Commercial Solutions

ATP Funded Cost Reduction



Hybrid Plastics™



Crystalline Solids

Wide melting range 24°C to 400°C+

Waxes

Liquids & Oils

Wide viscosity range 40cSt. to 400cSt

Summary

The Air Force is heavily invested in POSS Applications Research and Development

Currently one application is being 'flight-tested' for a technology transition

New applications are being investigated (e.g., batteries, capacitors, radomes)

The technology transfer to Hybrid Plastics **IS** a success story with significant volume increase and price reduction

POSS Nanotechnology Offers Versatility!!